

One of the novel techniques adopted for the proposed system would be multipass processing of packet preamble for acquisition of frequencies and timing of carrier and data symbols. The multipass approach is intended to eliminate as much synchronization error as possible at an early stage of packet preamble processing in order to reduce the inter-carrier interference, which can contribute significantly to the bit-error rate under adverse channel conditions.

Another novel signal-processing technique would be joint pilot- and data-aided

channel estimation, tracking, and equalization in each of the two frequency channels. This technique would not only increase the accuracy in the estimate of the channel effects, but also would support tracking of dynamic Doppler shifts, resulting in a much improved channel equalization under adverse channel conditions.

Another novel aspect of the design would be the use of (1) turbo cross-channel coding in the transmitter in conjunction with (2) diversity combining of signals in the receiver. The gain afforded by this combination of coding and fre-

quency and time diversity would help to counteract severe fading, especially for the case when both channels are simultaneously affected by deep fades.

*This work was done by Haiping Tsou, Scott Darden, Dennis Lee, and Tsun-Yee Yan of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1)*

*The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-40205.*

## Multipurpose Hyperspectral Imaging System

Features include high spectral and spatial resolution, without camera/target relative motion.

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A hyperspectral imaging system of high spectral and spatial resolution that incorporates several innovative features has been developed to incorporate a focal-plane scanner (U.S. Patent 6,166,373). This feature enables the system to be used for both airborne/spaceborne and laboratory hyperspectral imaging with or without relative movement of the imaging system, and it can be used to scan a target of any size as long as the target can be imaged at the focal plane; for example, automated inspection of food items and identification of single-celled organisms. The spectral resolution of this system is greater than that of prior terrestrial multispectral imaging systems. Moreover, unlike prior high-spectral-resolution airborne and spaceborne hyperspectral imaging systems, this system does not rely on relative movement of the target and the imaging system to sweep an imaging line across a scene.

This compact system (see figure) consists of a front objective mounted at a translation stage with a motorized actuator, and a line-slit imaging spectrograph mounted within a rotary assembly with a rear adaptor to a charged-coupled-device (CCD) camera. Push-broom scanning is carried out by the motorized actuator which can be controlled either manually by an operator or automatically by a computer to drive the line-slit across an image at a focal plane of the front objective. To reduce the cost, the system has been designed to integrate as many as possible off-the-shelf components including the CCD camera and spectrograph. The system has achieved high spectral and spatial resolutions by using a high-quality CCD camera, spectrograph, and front objective lens. Fixtures

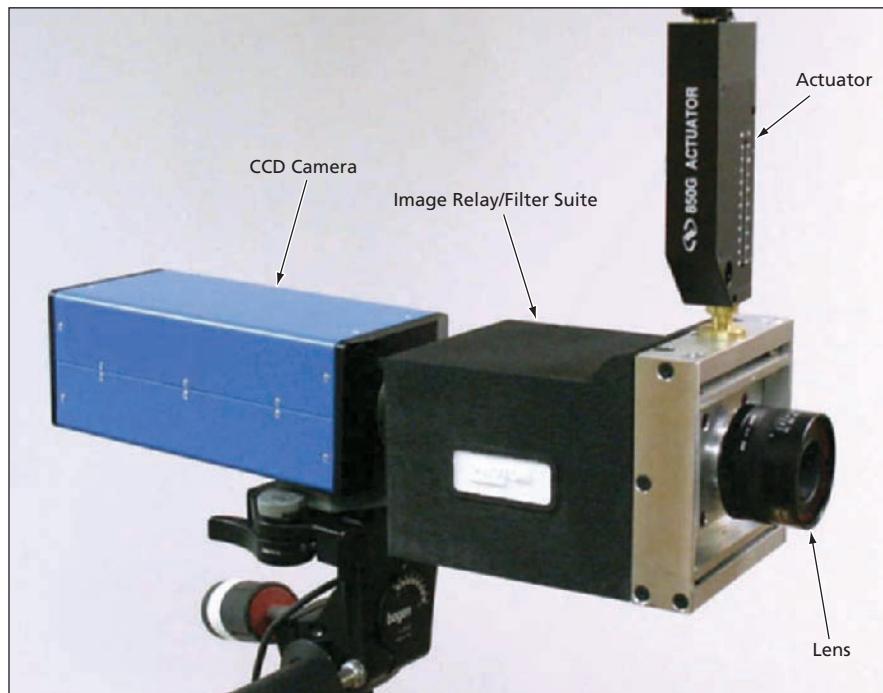
for attachment of the system to a microscope (U.S. Patent 6,495,818 B1) make it possible to acquire multispectral images of single cells and other microscopic objects.

To make it unnecessary to move the camera relative to the target or vice versa, the design of the system provides for lateral motion of the image on the focal plane. For this purpose, the front lens is mounted on a translational stage driven by a computer-controlled motor.

The system also includes a computer programmed with special-purpose operational software; frame-grabber, and motor-control circuit boards connected between

the computer on one hand and the CCD and motor, respectively, on the other hand; and light sources. The system can collect image data in as many as 1,040 spectral bands in the wavelength range from 400 to 1,000 nm.

The special-purpose operational software is a single computer program that controls all aspects of the acquisition and preprocessing of image data, performing functions that, heretofore, entailed the use of several different programs: The software controls the camera, scanning speed, and start and stop positions, and automatically drives the motorized actuator in push-



The Main Front Components of the imaging system are shown mounted on the tripod.

broom scanning. A user may utilize the program to invoke the CCD camera's user interface for customized configuration. Different spectral band-pass and spatial resolutions may be changed by different CCD vertical/horizontal binning factors. A calibration function is implemented for correcting spectral and spatial errors due to optical distortion of the front objective and spectrograph. The software then pre-processes the image data into hyperspectral image cubes (three-dimensional arrays of data indexed according to two spatial coordinates and a spectral coordinate). Next, the software can perform calibration, noise-removal, data-formatting, and subset-

ting operations; correct for spectral distortions; and create headers for image-data files to be subjected to further processing by other software (for example, the software described below), as instructed by the user. The program can also perform some image-inversion calculations and some statistical analysis of image data, and can detect image saturation.

By suitably modifying the operational software and adding special-purpose image-processing software, the system can be configured for automated inspection of food items on production lines. An example of this functionality is the development of a prototype version to process three- or

four-spectral-band images to detect fecal contamination of poultry carcasses on a conveyor belt at a rate of 180 carcasses per minute — about double the rate of a modern poultry-processing line.

*This work was done by Chengye Mao, David Smith, Mark A. Lanoue, Gavin H. Poole, Jerry Heitschmidt, and Luis Martinez of The Institute for Technology/Provision Technologies; and William A. Windham, Kurt C. Lawrence, and Bosoon Park of the Agricultural Research Service of the United States Department of Agriculture for Marshall Space Flight Center. For further information, contact the company at [info@pvttech.org](mailto:info@pvttech.org).  
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